Delegation Sketch: a Parallel Design with Support for Fast and Accurate Concurrent Operations

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Motivation

Example:

At any point in time, report how many packets from a given IP have been seen

- Exact answer \(\Rightarrow\) space proportional to number of unique IPs
- Approximate answer \(\Rightarrow\) constant space
  - Enough to summarize the input stream
  - Sketches are established tools for that
Challenges

- We focus on **how to parallelize sketches**

Parallelization is necessary:
  - High-speed networks $\Rightarrow$ Mops/sec on the sketch
  - Many-core platforms $\Rightarrow$ underutilized in sketches

4-way tradeoff:
  - Applications require fast insertions and queries
    - E.g. intrusion detection, traffic scheduling
  - Most parallel approaches focus on one of the two (with the exception of recent work[1])

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"Fast concurrent data sketches", A. Ringerg, et al., PPoPP’20
Our Work

**Delegation Sketch:** A parallelization design for sketches

Contributions:
- **Concurrent Insertions and queries**, at high rates
- Maintains high accuracy and low memory consumption
- Scales better than state-of-the-art on **hundreds of cores**
Delegation Sketch: Domain splitting

- Every key in the input domain is assigned an “owner” sketch and inserted there
- Queries are fast and accurate:
  - every key is in a specific sketch
Delegation Sketch: Delegation and Combining

- Threads aggregate multiple keys into filters locally, without communication
- Filters are the units of synchronization
- Full filters are delegated to the “owner” sketch

Filters Allow:
- Disjoint access parallelism
- Coarse-grained communication
Evaluation Results

Parameters: # threads & query rate

Delegation Sketch:
- **2-4X higher relative speedup** at higher query rates
- **Better scaling** at higher query rates
Evaluation Results

Accuracy

Error for each key (lower is better)

Delegation sketch:
- As accurate as the most accurate baseline (single-shared)

All keys in the stream
Delegation Sketch

- A parallelization scheme for high-rate traffic summarization
- Supports both **insertions and queries**
- Up to 2-4X higher throughput than next fastest baseline
- As accurate as the most accurate baseline
Backup slides
Evaluation Results

Parameter: input skew

Delegation Sketch:

- High throughput at medium-high skew, due to filters

*Note: different y-axis range*
Evaluation Results

Query Latency

![Graph showing query latency vs. threads and skew parameter]
Accuracy

Accuracy bounds for Delegation Sketch:

\[ f(i) \leq \hat{f}(i) \leq f(i) + \epsilon N' \text{ with probability } 1 - \delta \]

- \( f(i) \): the true frequency of key i
- \( \hat{f}(i) \): the reported estimate for key i
- \( \epsilon = e/w \) (w = number of buckets)
- \( N' = \) number of keys that hash to the same sketch
- \( \delta = e^{-d}, d = \) number of rows
Accuracy